Bio-inspired Surface for Water Directional Transport and Uniform Water Spreading

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Unidirectional liquid spreading is of significant interest for a wide range of applications, such as microfluidic devices, self-lubrication, controllable chemical reaction, and biomedical. Although the surfaces with wettable gradient or asymmetric nanowires could harness the liquid to spread unidirectionally, the spreading is remarkable slow over a short distance and just occurs with specific surface chemistry property. Nature inspired one-dimensional fibers from spider silks and cactus spines give a way of combining surface energy gradient and curvature gradient to drive the droplet directionally, while they are difficult to be applied as two-dimensional surfaces anticipated in microfluidics devices, biomedical devices and so on. Recently, continuous uni-directional liquid spreading with fast speed was firstly discovered on the peristome of Nepenthes alata as shown in Fig.1, which possesses superhydrophilic hierarchical microgrooves and duck-billed microcavities with arc-shaped edge and gradient wedge corner [1].

Inspired from the surface structure on peristome, a novel bio-inspired uni-directional liquid spreading surface was built via two-step and inclined UV exposure photolithography as shown in Fig.2. The controlling of its uni-directional liquid spreading was realized by changing surface wettability and structural features of microcavities as shown in Fig.3, and the underlying mechanisms were experimentally demonstrated [2,3]. Moreover, gradient Taylor rise was built to support the mechanism of uni-directional liquid transport on basis of traditional Taylor rise. Combining this structure surface with thermoresponsive material, a novel smart temperature-controlled uni-directional liquid spreading surface was carried out, which can be used in medical and microfluid devices [4].

As another typical natural surface with unique water transport function, tree frog toe pads possess superior wet friction as shown in Fig.4. This wet friction also comes from the characteristic surface structure i.e. hexagonal pillar. Liquid on the toe pad of tree frog demonstrated directional spreading from surrounded channels to the top of hexagonal pillars during separating from substrate. In this process, liquid film crushes into pieces and each pillar was left with a drop on it. This effect efficiently enhanced the friction under wet condition and can be applied in medical devices, such as surgical grasper [5].

Finally, all of these investigations were applied in the minimally invasive surgical devices to demonstrate their efficiency. On basis of uni-directional liquid transport mechanism, bio-inspired anti-adhesion electrosurgical knife was proposed and developed to prevent soft tissue adhesion. Experimental results shows that the anti-adhesion force of bio-inspired electrosurgical knife is reduced about 80% as compared with conventional electrosurgical knife. Bio-inspired anti-slipping grasper was also developed under the inspiration of tree frog toe pads. The wet friction force was improved about 20%, and the soft tissue deformation was clarified to be decreased about 100 times.

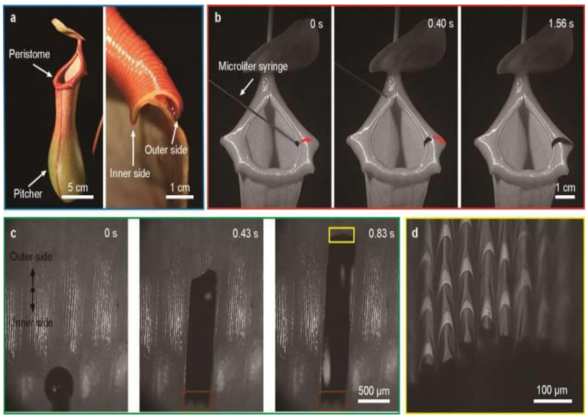

Fig. 1 Unidirectional Water transport on the the peristome of Nepenthes alata

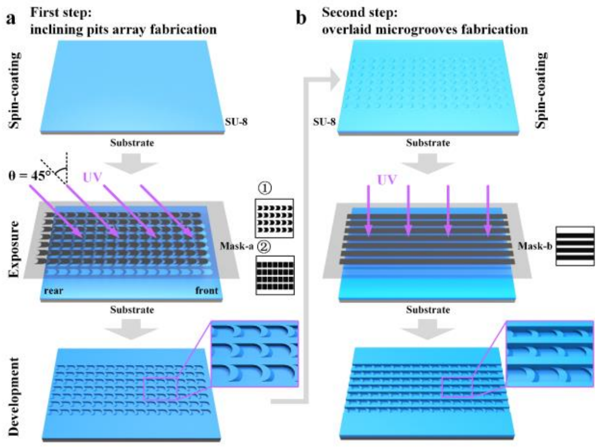

Fig. 2 Successive two steps of UV exposure processes to fabricate unidirectional water transport surface

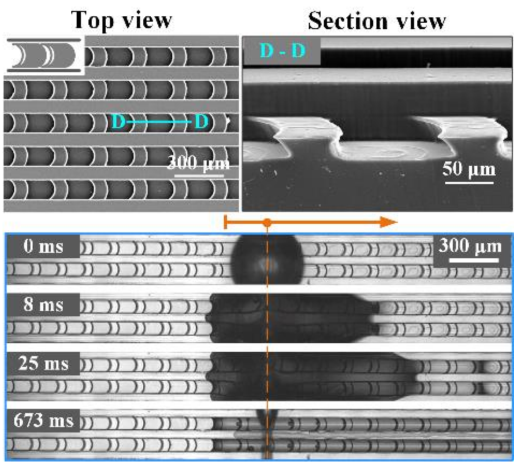

Fig. 3 The top view and section view SEM images of unidirectional water transport surface and its unidirectional water transport on the bio-inspired surface

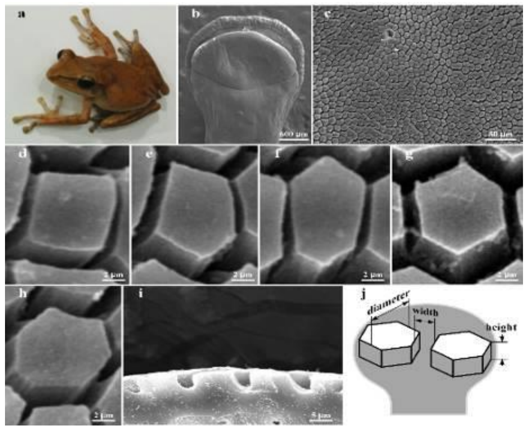

Fig. 4 SEM image of tree frog toe pads and its structural characteristics

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